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Losing sleep at the market: An empirical note on the daylight saving anomaly in Australia

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Abstract

The 'daylight saving effect' predicts that the mean weekend return following the spring and fall/autumn changes in daylight saving time is less than the mean weekend return throughout the rest of the year. With this market anomaly, the change in market participants' behaviour is linked with sleep desynchronosis and the change in circadian rhythm and its negative impact on sleep patterns. This study investigates the purported daylight saving effect in Australian equity market returns over the period 1979/80-2002/03 using parametric testing and regression analysis. After adjustments are made for heteroskedasticity and autocorrelation in the data, neither the transition to nor the movement from daylight saving is associated with returns that differ from other days. The results also show the absence of any significant weekend effect in the Australian equity market.

Keywords: Daylight saving time, daylight saving effect, weekend effect, market anomalies.

Introduction

In a recent provocative article, Kamstra et al. (2000) found that the average Friday-to-Monday stock return on daylight saving weekends was 200 to 500 percent larger than the average negative return for other weekends (the so-called 'weekend-effect' market anomaly) and thereby associated with a one-day loss of US$31 billion on the NYSE, AMEX and NASDAQ markets alone. Kamstra's et al. (2000) findings appeared to hold not only in the United States and Canada, where the transition to and from daylight saving is broadly similar, but also in the United Kingdom, whose patterns differ from that in North America, and to a lesser extent in Germany. On this basis, Kamstra et al. (2000: 1010) suggested that if daylight saving was associated with "…the sort of impact investigated here, an obvious policy implication is to do away with the time change altogether".

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The essence of Kamstra's et al (2000) argument is that the 'daylight saving effect' is linked with sleep desynchronosis associated with the change in the circadian rhythm and its (negative) impact on sleep patterns. Every Spring at 2:00 a.m. on the first Sunday in April US clocks are moved forward one hour, and the following Fall (Autumn) at 2:00 a.m. on the last Sunday in October clocks are moved back one hour. As with jet lag, where changes in sleep patterns are thought to persist up to five days for each one-hour time zone crossed (Waterhouse et al. 1997), the movement to daylight saving time also compresses the day, while the movement from daylight saving stretches it, and this also impacts upon sleep patterns. If, and as hypothesised by Kamstra et al. (2000: 1006), "…sleep desynchronosis causes market participants to suffer greater anxiety about a given situation, *ceteris paribus*, they may prefer safer investments and shun risk in trades during the trading day following such a disturbance in their sleep patterns…this could push down stock prices following daylight saving shifts when the desynchronosis is systematic".

Of course, the argument that shifts to and from daylight saving has an impact upon actual behaviour has parallels elsewhere. One possibility is that the change in photoperiod induced by daylight saving time may also have an effect on psychiatric presentation. The argument is that sleep deprivation, and the manipulation of circadian rhythm associated with the transition to daylight saving, alter the clinical state of depressed patients. Moreover, the successful use of 'light therapy' for treating seasonal affective disorder gives credence to the possibility that even a small shift in circadian rhythm has an influence on affective illness. Bick and Hannah (1986), for example, linked a 81 percent increase in depressed contacts and a 47 percent increase in psychosis-related presentations at a UK crisis intervention centre with the shift to daylight saving. However, in another UK study, Shapiro et al. (1990) examined the incidence of parasuicide presentations, psychiatric outpatient contacts and inpatient admission, and registered suicides following the start of daylight saving, but found no discernible impact through either the change in photoperiod or the small impact on the circadian rhythm.

A further possibility is the impact of daylight saving transition on traffic accidents through sleep desynchronosis and the change in circadian rhythm. Sullivan and Flannagan (2002), for example, found that pedestrians were three to nearly seven times more likely to be injured following transitions to and from daylight saving. Varughese and Allen (2001) also linked a small increase in fatal accidents with the Monday following the changeover in the US, while in a Canadian study, Coren (1996a, 1996b) measured a significant increase (up to some eight percent) in accident risk on the Monday following the spring change to daylight saving and a comparable decrease in the fall change from daylight saving. By way of contrast, Lambe and Cummings (2000) found that the sleep deprivation normally associated with the change over to daylight saving had no measurable impact on crash incidence in Sweden.

All the same, there are a number of complications associated with Kamstra's et al. (2000) purported daylight saving effect, which may not arise in non-financial market contexts. To start with, the daylight saving effects exists in parallel with the oft-examined weekend effect, for which a number of competing hypotheses have already been put forward and tested [see, for instance, Agrawal and Ikenberry (1994), Chang et al. (1993, 1998) and Wang and Erickson (1997)]. For example, the weekend effect has been linked to lags in the payment and cheque clearing settlements, to midweek time pressures on individuals, the tendency for financial advice to be given after Monday strategy-setting meetings, and to the larger percentage of purchases (sales) on Fridays (Mondays) at dealer ask (bid) prices (Kamstra et al. 2000). It may then be possible that the sleep desynchronosis associated with daylight saving weekends is just an alternative manifestation of this more usual market anomaly. For example, Pinegar (2002: 1256) countered that "the change in sleeping patterns from weekdays to weekends occurs with much greater frequency and is very plausibly more pronounced than the change in sleeping patterns between daylight-saving and non-daylight saving weekend. Thus sleep desynchronosis may contribute to the so-called 'day-of-the-week' effect on non-daylight saving Mondays also".

Another problem is that daylight saving transition weekends are by nature limited in number, and these may be juxtaposed with outliers. Once again, Pinegar (2002) questioned Kamstra's et al (2000) conclusions on the basis that in the last eighty years three of the largest percentage declines in the S&P 500 took place after a fall daylight-saving time change (most recently Monday 26 October 1987). In response, Kamstra et al. (2002) countered, "…while we do not believe that daylight-saving-time changes *cause* market crashes, we do believe that daylight-saving-time changes affect the degree of market fluctuations…we speculate that severe downturns are more likely following daylight-saving weekends, and we argue that the data support this contention" (original emphasis). Lastly, Pinegar (2000) also argues that the apparent corroboration offered by Kamstra's et al. (2000) inclusion of Canada, Germany and the United Kingdom in their analysis may be an illusion associated with the normal influence on them by the US market, and that such international evidence should then be treated more cautiously.

The purpose of the present paper is to add to this small but intriguing body of work the results of an analysis of the Australian equity market. To the author's knowledge this is the first of its kind in Australia, and adds significantly to the nascent literature concerning the economic benefits and costs of daylight saving. The paper itself is divided into four main areas. The first section reviews the concept of daylight saving. The second section explains the empirical methodology and data collection employed in the analysis. The third section discusses the results. The paper ends with some brief concluding remarks.

Daylight saving

For millennia, the measurement of time has been based on the position of the sun, with noon being denoted when it is highest in the sky. Even with mechanical clocks replacing sundials in the Middle Ages, the measurement of local (or true or apparent) solar time has been bound with observation of the sun at noon (or its indirect calculation by means of astronomical tables) and time accordingly varied continuously with longitude. Well into the nineteenth century time was a genuinely local matter, and most cities and towns used some form of solar time, usually reflected in a well-observed standard such as a church or town hall clock. Measurement of time in this manner was, of course, entirely appropriate to a society where the hours of work and leisure were dictated by the rising and setting of the sun and the technological limitations of artificial lighting.

However, in the latter half of the nineteenth century the inconsistencies of local solar time and the demands of railway timetabling in first Britain and then the United States started the process of standardising time by region and its replacement with Local Standard Time (LST). This opened the way for the eventual implementation of daylight saving. In Britain, uniform time, as credited to William Hyde Woolaston (1766-1828) and popularised by Abraham Follet Osler (1808-1903), led to the Great Western Railway voluntarily using Greenwich Mean Time (GMT) from November 1840. All other railways followed compulsorily in December 1847. By 1855, the majority of public clocks in Britain were set to GMT and full compliance was ensured in the *Statutes (Definition of Time) Act* of August 1880.

In the United States, the railways largely ignored early advocates of standardisation such as William Lambert in 1809 and Charles Dowd in 1870 until pressure by Canadian railway engineer Sandford Fleming led to the establishment of standard time meridians in both the United States and Canada in 1883. Fleming was also instrumental in establishing the *International Prime Meridian Conference* in Washington in 1884 that eventually divided the globe into 24 time zones, each 15 degrees of arc (or one hour in time apart) and reckoned from the Prime Meridian of Longitude in Greenwich (GMT). Since then GMT (as derived from astronomical observations) has been superseded for most practical purposes by the similar Coordinated Universal Time (UTC) as the worldwide standard for time and date (as based on an atomic clock).

The origins of daylight saving itself can be traced as far back as the eighteenth century. In a whimsical essay, Benjamin Franklin (1794) – US inventor, statesman and then minister to France – reasoned how rising and retiring earlier according to the sun would prove a considerable economy to the people of Paris:

> An accidental sudden noise waked me about six in the morning, when I was surprised to find my room filled with light…I got up and looked out to see what might be the occasion of it, when I saw the sun just rising above the horizon, from whence he poured his rays plentifully into my chamber, my domestic having negligently omitted, the previous evening, to close the shutters…if I had not been awakened so early in the morning, I should have slept six hours longer by the light of the sun, and in exchange have lived six hours the following night by candlelight; the latter being a much more expensive light than the former…I believe all who have common sense, as soon as they have learnt from this paper that it is daylight when the sun rises, will contrive to rise with him.

Later, London builder William Willett (1907) in a pamphlet entitled “The Waste of Daylight” outlined more fully the concept of daylight saving as it is known today [though in the form of an eighty minute gain achieved through four successive weekly jumps of twenty minutes during April]:

> [S]tandard time remains so fixed, that for nearly half the year the sun shines upon the land for several hours each day while we are asleep, and is rapidly nearing the horizon, having already passed its western limit, when we reach home after the work of the day is over. Under the most favourable circumstances, there then remains only a brief spell of declining daylight in which to spend the short period of leisure at our disposal. Now, if some of the hours of wasted sunlight could be withdrawn from the beginning and added to the end of the day, how many advantages would be gained by all, and in particular by those in the open air, when light permits them to do so, whatever time they have at their command after the duties of the day have been discharged.

However, it was not until World War I, and largely as a means of energy conservation by the combatants, that Daylight Saving Time (DST) was actually implemented. Starting with Germany and Austria on 30 April 1916, Belgium, Denmark, France, Italy, Luxembourg, the Netherlands, Norway, Portugal, Sweden and Turkey all adopted DST, along with Tasmania and the Canadian provinces of Nova Scotia and Manitoba. Britain began DST on 21 May 1916, followed by mainland Australia during the period 1 January 1917 to 25 March 1917.

The Canadian provinces of Newfoundland and Nova Scotia also started DST in 1917. The US enacted legislation on 19 March 1918 to begin DST on 31 March 1918 and this was held in place for the remainder of WWI and for another seven months in 1919.

In the United States, wartime DST proved generally unpopular and it continued in only a few states (Massachusetts, Rhode Island) and cities (Chicago, New York, Philadelphia) during the interwar period. However, during World War II the Roosevelt administration implemented year-round DST, now known as 'War Time', from 2 February 1942 to 30 September 1945. From 1946 to 1966 the states and localities again reverted to a patchwork of adherence, but by then some 100 million Americans in 36 states were observing DST in some form or another as defined by local or regional law.

In order to eliminate what were seen as costly inconsistencies in observance [the *Committee for Time Uniformity*, for example, disclosed that on a 35-mile bus route between Moundsville, West Virginia and Steubenville, Ohio, the driver and passengers were obliged to change time seven times] the Johnston administration under the *Uniform Time Act* of 1966 implemented DST from the last Sunday of April until the last Sunday of October, with exemptions for states whose legislatures voted to keep the entire state on standard time. Congress revised the act in 1972 such that if a state was in two or more time zones, exemptions could be made for different parts of the state, while on 4 January 1974 the Nixon administration extended DST to conserve energy during the OPEC oil crisis for the fifteen-month period to 27 April 1975. Finally, in 1986 the Reagan administration brought forward the start of DST from the last Sunday in April to the first Sunday, with no change to the ending date.

DST is currently observed in all US states and territories with the exception of Hawaii, American Samoa, Guam, Puerto Rico, the Virgin Islands and Arizona (excluding the Navajo Indian Reservation). In Indiana, seventy-seven counties (including Indianapolis the state capital) in the central portion remain on Eastern Standard Time (EST) year round, and hence do not use DST, while ten counties in the western portion in Central Standard Time (CST) use both CST and Central Daylight Time (CDT), and thus move to DST in summer. The remaining five counties in the eastern portion on EST move to Eastern Daylight Time (EDT) and therefore also use DST.

In Britain, DST was also used again during World War II though with clocks moving ahead of GMT by two hours in the summer and by one hour during the winter. Between 1968 and 1971 the policy was reinstituted and since then the issue of DST, which currently begins on the last Sunday of March and ends on the last Sunday of October, has been closely tied with lobbying for Britain to abandon GMT in favour of Central European Time (CET) (GMT +2 in summer and +1 in winter) and thereby bring it in line with the other members of the European Union, with the exception of Ireland (GMT) and Greece (GMT +2).

In common with the US and Britain, Australia also used DST as an energy conservation measure during WWII operating from 1 January to 29 March 1942, 27 September 1942 to 28 March 1943 and 3 October 1943 to 26 March 1944 (with the exception of Western Australia in the final period). DST was not used again until 1967/68 to 1970/71 when Tasmania (with the exception of King Island) initially adopted it as a means of managing the severe shortage in hydroelectric power associated with a drought. The positive experience with DST in Tasmania prompted it to champion a trial season in 1971/72 that was supported by all states and territories except Western Australia and the Northern Territory.

Participation in DST by the various states and territories since the trial season has been erratic. Queensland did not adopt DST again until 1989/90, and then only until 1991/92 when it was abandoned following the results of a referendum. In the same thirty-year period Western Australia only followed DST in 1974/75, 1983/84 and 1991/92 and also discontinued use following a referendum on the matter. The Northern Territory has never adopted DST. Usage in the remaining states and territory was largely consistent until 1981/82 when Victoria, the ACT and South Australia ended in early March, NSW in late March and Tasmania in early April, and 1982/83 when New South Wales, the ACT, Victoria and South Australia ended DST three weeks earlier than Tasmania. Since then, there have been at least two sets of start and end dates for DST in Australia (with the exception of 1983/84 and 1984/85), with three different sets of start and end dates in 1990/91, 1993/94 and 1994/95, though since 1995/96 Victoria, NSW, ACT and SA (but not Tasmania) have begun and ended DST at the same time.

Putting aside the one-off adjustments to DST for festivals and special events that have characterised its usage in the past, even a normal year of daylight saving in Australia involves some degree of complexity. Without DST Australia has three time zones spaced over two hours: Australian Eastern Standard Time (AEST) (UTC +10) in Queensland, NSW, the ACT, Victoria and Tasmania, Australian Central Standard Time (ACST) (UTC +9.5) in the Northern Territory and South Australia, and Australian Western Standard Time (AWST) (UTC +8) in Western Australia. In 2002/03, the move to DST entailed two additional time zones and an increase in the east west time spread of one hour: Tasmania on Australian

Eastern Daylight Time (AEDT) (UTC +11) from 6 October, Victoria, NSW and the ACT on AEST (UTC + 10) until the shift to AEDT (UTC +11) on 27 October, South Australia on ACST (UTC +9.5) until 27 October and then Australian Central Daylight Time (ACDT) (UTC +10.5), Queensland on AEST (UTC +10), the Northern Territory on ACST (UTC + 9.5) and Western Australia on AWST (UTC +8). On 30 March 2003 DST ended in all observing states and territories and the number of time zones and time spread fell again to three zones and two hours, respectively.

Outside of the US, Britain and Australia, DST is found in nearly all developed economies (with the exception of Japan) and many developing economies in some form or another, though observance is somewhat unpredictable. As a general rule, it is less prevalent in equatorial and sub-tropical (lower latitudes) countries where the gain in sunlight in summer over winter is less. Russia and most states of the former USSR observe DST with all of Russia's eleven time zones two hours ahead of standard time in summer and one hour in winter. All members of the European Union implement DST with summer time running from the last Sunday in March through the last Sunday in October. Parts of the Caribbean, Cuba, Israel, Egypt, Syria, Iraq, Iran, Chile, China, Mongolia, Paraguay, New Zealand, and even Antarctica, also observe DST. DST is found across Canada with the exception of Saskatchewan and in Brazil excluding equatorial Brazil. Mexico also uses DST, however the border city of Sonora has dispensation to align itself with non-daylight saving Arizona (Waxman 1998), while there have been moves by the left-wing mayor of Mexico City to also opt out of DST (Anonymous 2001).

Research method and data

Two dates are relevant for countries in the northern hemisphere implementing summer time DST: (i) a Sunday a.m. starting time and date, usually in early April, and (ii) a Sunday a.m. ending time and date, normally in late October in the same year. In the southern hemisphere, as in Australia, the starting and ending months are reversed and in succeeding years. However, one complication that does exist in Australia is that not all states and territories currently use DST, and of those that do the timing and adherence to the usual starting and ending dates has varied over the last several decades. As shown in Table 1, of Australia's six states and two territories only New South Wales (NSW), Victoria (VIC), South Australia (SA), Tasmania (TAS) and the Australian Capital Territory (ACT) have implemented DST annually since 1979/80, while Queensland (QLD) and Western Australia (WA) only adopted

DST spasmodically, from 1989/90 to 1991/92 and in 1983/84 and 1991/92, respectively. The Northern Territory (not shown) has never used DST.

Moreover, even amongst practicing states there is much variation in the dates at which DST starts and ends such that over the period 1979/80 to 2002/03 there have been either one or two different starting dates and between one and three ending dates. However, this is not unlike the situation in other federations such as the United States and Canada. For example, in the US only 36 of the 50 states had adopted DST in the 1960s and even today Hawaii, Arizona, most of Indiana and none of the territories use DST, nor does Saskatchewan in Canada. In order to reflect these differences in the current analysis, two sets of starting dates and three sets of ending dates are identified.

The first set of starting dates are where the most populous states of NSW and VIC both shift to DST at the same time. This accounts for 24 cases in the 24 years in the sample and on most occasions include most of the remaining states and territories. The second set is when a state or territory other than NSW or VIC commences DST on some other date. This represents 11 cases in 24 years. The other set of dates is the DST ending dates and these comprise three categories: (i) occasions when NSW and VIC shifted from DST at the same times (19 cases), (ii) dates when NSW and VIC moved out of DST at different times (4 cases in each respect) and (iii) dates when a state or territory other than NSW and VIC shifted out of DST (8 cases) at a different time to NSW and VIC. As before, at least some other states and territories may also have moved out of DST at these times. Accordingly, in the twenty-four year sample there have been thirty-five weekends in Australia where DST started at 2:00 a.m. on Sunday and thirty-five weekends where DST ended on Sunday at 3:00 a.m.

To test for the economic effect of daylight saving time change we look at the first trading day following the transition to or from DST. The data employed in the study are market returns drawn from the Australian Stock Exchange (ASX) over the period 2 January 1980 to 5 May 2003. Both the All Ordinaries Price and Accumulation (including dividends and capitalisation changes) Indices are used. Following Kamstra et al. (2001, 2002) and Pinegar (2002) a series of daily raw returns are calculated of which three categories are identified. These are: (i) a weekend return calculated from the Friday and Monday closing prices for weekends that do not include a DST starting or ending Sunday, (ii) a DST starting and ending weekend return calculated using the Friday and Monday closing prices for weekends including a DST starting and ending Sunday, and (iii) other days being those other than DST and non-DST weekends.

The DST starting and ending weekends are further categorised according to the different sets of starting and ending dates discussed above.

The basic hypothesis examined in this analysis is that the change to DST impacts upon sleep patterns in such a way that the daily returns for the next trading day following such a transition will differ from other days. Further, since the transition to (and from) DST has the effect of stretching (compressing) the day, and thereby having a negative (positive) effect on sleep patterns, the returns for the next trading day will be less (more) than other day returns. Finally, since the ‘daylight saving effect’ exists in parallel to the usual ‘weekend effect’ the magnitude of the change will be larger (smaller) than the expected (negative) weekend effect.

Two approaches are used to test these hypotheses. The first involves a descriptive analysis of the mean returns and tests of equality of these means using parametric analysis following Kamstra et al. (2000). As a rule, the mean return for the start of daylight saving is expected to be negative and less than the (negative) return for other weekends, while the mean return for the end of daylight saving can be either negative or positive, though the mean return should be higher than that for daylight saving or other weekends. The second is a regression-based approach where daily market returns are regressed against variables indicating the presence of daylight saving and weekend effects:

$$RTN_t = \beta_0 + \beta_1 WKD_t + \beta_2 STT_t + \beta_3 END_t + \varepsilon_t \qquad (1)$$

where RTN_t is the daily Monday to Friday market return at time t, STT is a dummy variable that equals one on a Monday following a weekend when DST started, END a dummy variable that equals one on a Monday following a weekend when DST ended, WKD a dummy variable that equals one for all other Mondays, β are coefficients to be estimated and ε is the error term. This approach follows that used Pinegar (2002). Following the hypotheses presented, the signs on the coefficients for WKD and STT are both expected to be negative, though the magnitude of STT is hypothesised to be larger than WKD, while the hypothesised sign on the coefficient for END is positive.

Empirical findings

Table 2 presents the summary of descriptive statistics for daily market returns. These are categorised according to the daylight saving and weekend effects hypothesised: namely, (i) non-DST starting or ending weekends, (ii) DST starting weekends common to NSW and VIC, (iii) DST ending weekends common to NSW and VIC, (iv) DST ending weekends for NSW but not VIC, (v) DST ending weekends for VIC but not NSW, (vi) DST starting weekends for other states and territories that were not shared by NSW and/or VIC, (vii) DST ending weekends for other states and territories that that were not shared by NSW and/or VIC, and (viii) all other days. Price returns are depicted in the upper portion of Table 1, while accumulation returns (including dividends and capitalisation changes) are presented in the lower portion. Sample means, trimmed means, medians, standard deviations, minimums, maximums, skewness, kurtosis and t-statistics and *p*-values for the equality of means are reported. Tests of equality of means are also included, comparing the mean returns for all other categories to other day returns and for all other categories to weekend returns.

At first impression, there appears to be some evidence of both the weekend and daylight saving effects in the Australian stock market. In terms of price returns, the mean weekend return (0.00017) is less that for other days (0.00039) while the mean DST starting returns are negative for both NSW and VIC (-0.00204) and other states (-0.00317) and generally positive for the DST ending returns (NSW and VIC 0.00182, NSW 0.00313, VIC 0.00481 and other states -0.00534). These mean price returns are broadly comparable to mean accumulation returns with the exception that the starting DST returns for NSW are no longer negative.

However, the *t*-tests comparing these mean returns to other days and weekends indicate that few of these differences are statistically significant. The starting DST mean price return is significantly less than other days at the .10 level suggesting that the mean return for Mondays following the introduction of DST in NSW and VIC is six times less than other days, while the return for other states starting DST is about thirteen times less. But these mean differences are no longer significant when specified in terms of returns on the accumulation index. In that instance, only the mean return for other states starting and ending DST are significant (at the .10 and .05 levels, respectively) suggesting mean accumulation returns are between six and nine times less for Mondays following the starting and ending of DST in states other than NSW and VIC where such dates differ.

Significance tests for the differences of means as compared to weekend returns offer a similar picture. For the price index, only the mean returns for other states ending DST is significant at a conventional level but does not conform to the hypothesised direction, whereas in the accumulation index the start and end of DST in states and dates other than NSW and VIC are also significant at the .10 level. In sum, the tests of differences in means show that price returns for Mondays following the introduction of DST are less than the returns for others days but only where DST has started on the same day in both NSW and VIC or where another state or territory has introduced DST on a day that differs from NSW and VIC. For accumulation returns, the mean return is less for Mondays following both the start or ending of DST in a state other than NSW and VIC. Lastly, the mean return for DST starting weekends in accumulation terms and DST ending weekends in price and accumulation returns is significantly less than other weekend returns, but only for DST starting and ending dates outside of NSW and/or VIC.

The estimated coefficients and standard errors of the parameters detailed in (1) are presented in Table 3. The upper portion of Table 3 is where the dependent variable is specified as daily Monday to Friday price returns, while the lower portion details the results of regressions where daily accumulation returns comprise the dependent variable. The independent variables in all instances are dummy variables for DST starting (*STT*) and ending (*END*) and other weekends (*WKD*). However, in the first regression for price and accumulation returns, the dummy variables are identified for all DST starting and ending dates, while in the second regression in each case these are DST starting and ending dates in NSW and/or VIC only. Three different standard errors, *t*-statistics and *p*-values are calculated and presented in Table 3 for each of the four regression models. These are standard errors, *t*-statistics and *p*-values obtained by: (i) ordinary least squares (Least Squares), (ii) those employing corrections for heteroskedasticity of unknown form (White), and (iii) those incorporating corrections for heteroskedasticity and autocorrelation of unknown form (Newey-West).

Once again, the signs on the estimated coefficients appear to offer *prima facie* support for the posited daylight saving effect. The signs on *WKD* and *STT* are always negative, with the magnitude of *STT* being larger, suggesting the presence simultaneously of both the weekend and daylight saving effect market anomalies. That is, the weekend effect is associated with a lower mean return than others days and the start of DST is linked with a larger negative effect as compared to other weekends. The sign on *END* is likewise consistence with the hypothesis that mean returns following the end of DST are positive, or at least higher, than the mean returns of DST starting and non-starting weekends. However, only in the case of DST starting weekends are the least squares estimates of market returns significant. After corrections are made for heteroskedasticity (White) and heteroskedasticity and autocorrelation (Newey-West) none of the parameters are significant at any conventional level, irrespective of whether market returns are specified in price or accumulation terms, or whether the transition weekends are in all Australian states and territories or only NSW and VIC. On average, weekend returns that follow the start or end of daylight saving time are not abnormally high or low when compared to other weekends or other days of the week. Furthermore, there is no significant difference between weekend returns as defined (Friday-Monday) and daily returns Monday-Tuesday, Tuesday-Wednesday, Wednesday-Thursday and Friday-Thursday.

Concluding remarks and policy recommendations

The present study employs parametric analysis to test for the 'daylight saving effect' market anomaly in the Australian stock market. At first there would appear to be a small of amount of empirical evidence to support the conjecture that the transition to (and from) daylight saving, as variously defined, is associated with a lower (higher) mean market return than either other weekends or other days. However, after adjustments are made for heteroskedasticity and/or autocorrelation, neither the transition to daylight saving nor the movement from daylight saving is associated with returns that are statistically significant from other days, let alone other weekends. These results lie counter to the US, UK and Canadian findings of Kamstra et al. (2000, 2002) but are similar to the results of Pinegar (2002: 1255) who also found that the hypothesis that "…mean weekend returns are significantly lower following changes in daylight-saving vis-à-vis other weekends is not robust". Indeed, there would also appear to be no evidence in this study to support even the well-investigated hypotheses underlying the weekend effect market anomaly. Daylight saving in Australia may be opposed on a number of policy grounds, but it would appear that adverse affects on capital markets should not be one of them.

Of course, the sleep desynchronosis linked with the transition to and from daylight saving may have a role to play in financial markets that has not been investigated here. All of these indicate future directions for research. One possibility follows the suggestion of Pinegar (2002) that changes in sleep patterns may amplify the impact of negative news and that the true impact of daylight saving, or indeed any other source of sleep disturbance, may be measured by how daylight saving transition weekends affect the magnitude of positive and/or negative changes, rather than positive and/or negative changes themselves. Another possibility is that the adjustment process to daylight saving may be slower than that hypothesised, and that the full effect of sleep desynchronosis may be felt at less significance over several days rather than the twenty-four hours employed here. Lambe and Cummings (2000), for example, point out that the adjustment process in daylight saving may be longer than jet lag because of the absence of new external reference points to the change in time. Finally, it may well be the case that the daylight saving effect, like many other market anomalies, is felt more keenly in small companies than large. Since this study uses market-weighted stock indices as against price or equal-weighted market indices or small cap sector indices, such differences may well be obscured.

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TABLE 1. *Implementation dates of daylight saving time within Australia, 1979/80 – 2002/03*

	NSW		VIC		QLD		SA		WA		TAS		ACT		Total	
Year	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
1979-80	28-Oct	2-Mar	28-Oct	2-Mar	–	–	28-Oct	2-Mar	–	–	28-Oct	2-Mar	28-Oct	2-Mar	1	1
1980-81	26-Oct	1-Mar	26-Oct	1-Mar	–	–	26-Oct	1-Mar	–	–	26-Oct	1-Mar	26-Oct	1-Mar	1	3
1981-82	25-Oct	4-Apr	25-Oct	7-Mar	–	–	25-Oct	7-Mar	–	–	25-Oct	28-Mar	25-Oct	7-Mar	1	2
1982-83	31-Oct	6-Mar	31-Oct	6-Mar	–	–	31-Oct	6-Mar	–	–	31-Oct	27-Mar	31-Oct	6-Mar	1	1
1983-84	30-Oct	4-Mar	30-Oct	4-Mar	–	–	30-Oct	4-Mar	30-Oct	4-Mar	30-Oct	4-Mar	30-Oct	4-Mar	1	1
1984-85	28-Oct	3-Mar	28-Oct	3-Mar	–	–	28-Oct	3-Mar	–	–	28-Oct	3-Mar	28-Oct	3-Mar	1	1
1985-86	27-Oct	16-Mar	27-Oct	16-Mar	–	–	27-Oct	16-Mar	–	–	27-Oct	2-Mar	27-Oct	16-Mar	1	2
1986-87	19-Oct	15-Mar	19-Oct	15-Mar	–	–	19-Oct	15-Mar	–	–	19-Oct	15-Mar	19-Oct	15-Mar	1	1
1987-88	25-Oct	20-Mar	25-Oct	20-Mar	–	–	25-Oct	20-Mar	–	–	25-Oct	20-Mar	25-Oct	20-Mar	1	1
1988-89	30-Oct	19-Mar	30-Oct	19-Mar	–	–	30-Oct	19-Mar	–	–	30-Oct	19-Mar	30-Oct	19-Mar	1	1
1989-90	29-Oct	4-Mar	29-Oct	18-Mar	29-Oct	4-Mar	29-Oct	18-Mar	–	–	29-Oct	18-Mar	29-Oct	4-Mar	1	2
1990-91	28-Oct	17-Mar	28-Oct	3-Mar	28-Oct	17-Mar	28-Oct	3-Mar	–	–	28-Oct	3-Mar	28-Oct	17-Mar	1	2
1991-92	27-Oct	1-Mar	27-Oct	1-Mar	27-Oct	1-Mar	27-Oct	22-Mar	27-Oct	1-Mar	27-Oct	27-Oct	27-Oct	1-Mar	1	3
1992-93	25-Oct	7-Mar	25-Oct	7-Mar	–	–	25-Oct	7-Mar	–	–	4-Oct	7-Mar	25-Oct	7-Mar	2	2
1993-94	31-Oct	6-Mar	31-Oct	6-Mar	–	–	31-Oct	20-Mar	–	–	31-Oct	27-Mar	31-Oct	6-Mar	2	3
1994-95	30-Oct	5-Mar	30-Oct	26-Mar	–	–	30-Oct	26-Mar	–	–	2-Oct	26-Mar	30-Oct	5-Mar	2	3
1995-96	29-Oct	31-Mar	29-Oct	31-Mar	–	–	29-Oct	31-Mar	–	–	1-Oct	31-Mar	29-Oct	31-Mar	2	1
1996-97	27-Oct	30-Mar	27-Oct	30-Mar	–	–	27-Oct	30-Mar	–	–	6-Oct	30-Mar	27-Oct	30-Mar	2	1
1997-98	26-Oct	29-Mar	26-Oct	29-Mar	–	–	26-Oct	29-Mar	–	–	5-Oct	29-Mar	26-Oct	29-Mar	2	1
1998-99	25-Oct	28-Mar	25-Oct	28-Mar	–	–	25-Oct	28-Mar	–	–	4-Oct	28-Mar	25-Oct	28-Mar	2	1
1999-00	31-Oct	26-Mar	31-Oct	26-Mar	–	–	31-Oct	26-Mar	–	–	3-Oct	26-Mar	31-Oct	26-Mar	2	1
2000-01	27-Aug	25-Mar	27-Aug	25-Mar	–	–	29-Oct	25-Mar	–	–	27-Aug	25-Mar	27-Aug	25-Mar	2	1
2001-02	28-Oct	31-Mar	28-Oct	31-Mar	–	–	28-Oct	31-Mar	–	–	7-Oct	31-Mar	28-Oct	31-Mar	2	1
2002-03	27-Oct	30-Mar	27-Oct	30-Mar	–	–	27-Oct	30-Mar	–	–	6-Oct	30-Mar	27-Oct	30-Mar	2	1

Source: Commonwealth Bureau of Meteorology. Notes: NSW – New South Wales, VIC – Victoria, QLD – Queensland, SA – South Australia, WA – Western Australia, TAS – Tasmania, ACT – Australian Capital Territory. Remaining state/territory of Northern Territory has never implemented Daylight Saving Time. Start – starting date of Daylight Saving Time, end – ending date of Daylight Saving Time. In all cases listed the change to Daylight Saving Time took place at 0200 hours Local Standard Time on the day concerned, and from Daylight Saving Time to Local Standard Time at 0300 hours. All transitions to and from DST are on Sundays. Total is the number of different start and end dates across the states and territories in each year.

TABLE 2. Descriptive analysis of daily return data

		Number	Mean	Trimmed Mean	Median	Std. Deviation	Minimum	Maximum	Skewness	Kurtosis	Other Days *t*-tests		Weekend *t*-tests	
All Ordinaries Price Index	Other Days	4870	0.00039	0.00049	0.00036	0.00927	-0.24995	0.06254	-4.35098	113.37800	–	–	-0.707	(0.240)
	Weekend	1148	0.00017	0.00036	0.00000	0.00965	-0.08096	0.06850	-0.63299	9.17159	0.707	(0.240)	–	–
	NSW & VIC Start	24	-0.00204	0.00018	-0.00011	0.01483	-0.06555	0.01318	-3.61138	15.68260	1.277	(0.100)	1.098	(0.136)
	NSW & Vic End	19	0.00182	0.00140	0.00176	0.00787	-0.00935	0.02049	0.68897	0.24247	-0.672	(0.251)	-0.740	(0.230)
	NSW End	4	0.00313	0.00333	0.00492	0.00649	-0.00568	0.00835	-1.09243	0.00336	-0.591	(0.277)	-0.612	(0.270)
	VIC End	4	0.00481	0.00512	0.00760	0.00730	-0.00586	0.00989	-1.72021	2.92337	-0.955	(0.170)	-0.961	(0.169)
	Other State Start	11	-0.00317	-0.00318	-0.00546	0.00836	-0.01657	0.01049	0.01102	-0.91861	1.272	(0.100)	1.144	(0.127)
	Other State End	8	-0.00534	-0.00499	-0.00243	0.00813	-0.01985	0.00296	-0.85440	-0.46222	1.745	(0.041)	1.610	(0.054)
All Ordinaries Accumulation Index	Other Days	4870	0.00051	0.00061	0.00048	0.00924	-0.24986	0.06420	-4.38696	114.92855	–	–	0.005	(0.498)
	Weekend	1148	0.00051	0.00065	0.00000	0.00986	-0.08007	0.07067	-0.46735	8.72164	-0.005	(0.498)	–	–
	NSW and VIC Start	24	-0.00267	-0.00042	-0.00005	0.01591	-0.06368	0.01323	-2.85455	9.66039	0.976	(0.170)	1.537	(0.063)
	NSW and Vic End	19	0.00213	0.00158	0.00205	0.00806	-0.00788	0.02189	0.78203	0.42161	-0.763	(0.223)	-0.712	(0.239)
	Other NSW End	4	0.00336	0.00358	0.00533	0.00658	-0.00565	0.00843	-1.15718	0.26894	-0.618	(0.269)	-0.578	(0.282)
	Other VIC End	4	0.00514	0.00545	0.00790	0.00742	-0.00562	0.01040	-1.64534	2.59180	-1.004	(0.158)	-0.940	(0.174)
	Other State Start	11	-0.00328	-0.00331	-0.00545	0.00824	-0.01658	0.01048	0.03255	-0.79439	1.359	(0.087)	1.271	(0.100)
	Other State End	8	-0.00506	-0.00470	-0.00216	0.00797	-0.01958	0.00298	-0.91135	-0.23699	1.704	(0.045)	1.594	(0.056)

Notes: DST – daylight saving time, Number – Number of observations in category, NSW & VIC Start (End) - starting (ending) DST weekend mean return where NSW and Victoria start (end) DST on the same date, NSW (VIC) End – ending DST weekend mean return where NSW (Victoria) end DST on different dates, Other State Start (End) – starting (ending) DST weekend mean return for states other than NSW and Victoria where different to NSW & VIC start (end), Weekend – all non-DST start/end weekend mean returns, Other Days – all days other than DST and non-DST weekend mean returns. Five percent trimmed mean. Critical values at the .05 level for skewness and kurtosis are: Other Days (0.035, 0.070), Weekend (0.072, 0.145), NSW & VIC Start (0.500, 1.000), NSW & Vic End (0.562, 1.124), NSW End (1.225, 2.449), VIC End (1.225, 2.449), Other State Start (0.739, 1.477), Other State End (0.866, 1.732), respectively. Levene's test for equality of variances determines whether the *t*-statistics and *p*-values for equality of means assume equal or unequal variances. Figures in brackets are *p*-values, Other Days *t*-tests – one-sided tests of equality of means to Other Days mean returns, Weekend *t*-tests – one-sided tests of equality of means to Weekend mean returns. Sample period 2 January 1980 to 5 May 2003.

TABLE 3. Estimated coefficients and standard errors from daylight saving regression models

				Least Squares			White			Newey-West	
Model	Variable	Coefficient	Std. error	*t*-statistic	*p*-value	Std. error	*t*-statistic	*p*-value	Std. error	*t*-statistic	*p*-value
All Ordinaries Price Index – All states & territories	CNS	0.0004	0.0001	2.8806	0.0040	0.0001	2.9087	0.0036	0.0001	2.6197	0.0088
	WKD	-0.0002	0.0003	-0.7053	0.4807	0.0003	-0.6893	0.4907	0.0003	-0.6980	0.4852
	STT	-0.0028	0.0016	-1.7536	0.0795	0.0022	-1.2802	0.2005	0.0021	-1.3084	0.1908
	END	0.0003	0.0016	0.1813	0.8561	0.0014	0.2104	0.8334	0.0014	0.2012	0.8405
All Ordinaries Price Index – NSW & Victoria only	CNS	0.0004	0.0001	2.7564	0.0059	0.0001	2.7836	0.0054	0.0001	2.5046	0.0123
	WKD	-0.0002	0.0003	-0.6489	0.5164	0.0003	-0.6342	0.5260	0.0003	-0.6420	0.5209
	STT	-0.0024	0.0019	-1.2600	0.2077	0.0030	-0.8130	0.4162	0.0029	-0.8269	0.4083
	END	0.0021	0.0018	1.1549	0.2482	0.0014	1.4806	0.1388	0.0014	1.4772	0.1397
All Ordinaries Accumulation Index – All states & territories	CNS	0.0005	0.0001	3.7616	0.0002	0.0001	3.8203	0.0001	0.0001	3.4455	0.0006
	WKD	0.0000	0.0003	0.0050	0.9960	0.0003	0.0048	0.9961	0.0003	0.0049	0.9961
	STT	-0.0034	0.0016	-2.1140	0.0346	0.0023	-1.4579	0.1449	0.0023	-1.4866	0.1372
	END	0.0005	0.0016	0.2911	0.7710	0.0014	0.3352	0.7375	0.0014	0.3209	0.7483
All Ordinaries Accumulation Index – NSW & Victoria only	CNS	0.0005	0.0001	3.6375	0.0003	0.0001	3.6947	0.0002	0.0001	3.3301	0.0009
	WKD	0.0000	0.0003	0.0623	0.9503	0.0003	0.0600	0.9521	0.0003	0.0609	0.9515
	STT	-0.0032	0.0019	-1.6425	0.1005	0.0032	-0.9911	0.3217	0.0031	-1.0060	0.3144
	END	0.0023	0.0018	1.2524	0.2105	0.0014	1.5758	0.1151	0.0014	1.5729	0.1158

Notes: Dependent variable is daily stock returns on price and accumulation index 2 January 1980 to 5 May 2003. CNS – constant, WKD – non-DST start/end weekend dummy variable, STT – DST starting weekend dummy variable, END – DST ending weekend dummy variable, All States and Territories refers to models including all Australian DST starting and ending weekend dummy variables, NSW and Victoria only model refers to models including only NSW/Victoria DST starting and ending weekend dummy variables. Least squares – standard errors, *t*-statistics and *p*-values from ordinary least squares, White – standard errors, *t*-statistics and *p*-values employing corrections for heteroskedasticity of unknown form following White (1980), Newey-West – standard errors, *t*-statistics and *p*-values employing corrections for heteroskedasticity and autocorrelation of unknown form following Newey and West (1987).